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55 Johnson Street
Brooklyn 1, New York

Report R-222.23-53, PIB-167.23
Contract No. NObsr-43360
Index No. 100-402

BIMONTHLY PROGRESS REPORT

For the Months of

February 1953 - March 1953

on

Navy Contract NObsr-43360

"Attenuators"

Title Page
7 Pages of Text
1 Page of Tables
25 Pages of Figures

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Brooklyn 1, New York
April 9, 1953

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I. Scope of the Program

The present phase of the program is based upon the following objectives:

1. The development of a variable coaxial attenuator for 7/8" coaxial line with broadband characteristics.
2. The development of a magnetic attenuator.
3. The measurement of phase-shift characteristics of attenuators designed for the frequency range of 2600 - 10,000 mc/sec.
4. The design of fixed coaxial attenuators for 3/8" coaxial line.
5. The development of high-power broadband probe-type attenuators.

II. Detailed Data*

A. Variable 7/8" Coaxial Attenuator

The measurements of attenuation and VSWR presented by the specially designed IRC card described in the last report have been completed. After eliminating some resonance phenomena, it has been possible to obtain a uniform behavior over the frequency range 1500 - 5200 mc/sec. with a maximum attenuation of 35 db or more and VSWR values less than 1.3 in the range 2500 - 5200 mc/sec. and less than 1.6 in the remaining range 1500 - 2500 mc/sec. Figs. MRI-13022, MRI-13023, MRI-13139, and MRI-13140 contain the final results.

During the experimentation, it has been observed that the series coupling capacitance C, which varies with penetration and is a controlling element for the attenuator unit, must be adjusted so as to avoid occurrence of resonance phenomena. This requires that the thickness of the cellophane coating on the graphite layer of the IRC card be made large enough. In addition, by using slightly different IRC cards, it has been found that neither the actual terminal curve of the graphite coating, nor the small nonuniformities introduced by the vertical slits are critical. For instance, satisfactory results have been obtained using a card with a triangular terminal boundary in the form of a penetrating wedge.

Although the unit is operating satisfactorily in the laboratory, it is felt the dependence of the db calibration upon the frequency and the care required in the adjustment of the series coupling capacitance C make it somewhat inconvenient for industrial use. For this reason, a new design of the

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* Contributors to this report include Mr. H. Rapaport, Dr. L. M. Vallese, and Mr. M. Wind.

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attenuator unit is being studied. The basic idea underlying this design is the replacement of the series capacitance, which necessarily must be very small, with a parallel one. In the arrangement, a fixed card of small admittance per unit length is placed in the attenuator unit. The card makes ohmic contact with inner and outer conductor, while it is protected elsewhere with cellophane. Then, a metallic plate connected with the outer conductor is lowered inside in such a way as to shunt capacitively portion of the resistive coating of the fixed card. Since the capacitive reactance between the metallic plate and the resistance card is very low, the resulting attenuator element is almost purely ohmic. One can expect therefore that the db calibration will be independent of frequency. A new unit based on this principle is at present in construction.

B. Magnetic Attenuator

1. Description

As described in the last bimonthly report, a special unit has been constructed to facilitate both a-c and d-c measurements of the characteristics of ferromagnetic materials in a coaxial system. Fig. MRI-13141 shows a schematic diagram of the test unit and circuit.

The longitudinal magnetizing coil consists of 3025 turns of No. 20 wire (diameter 3.196 mils) wrapped in a helix. The resistance of this coil is 13.5 ohms and the inductance is 0.1 henry (at 20°C).

In order that the data obtained may be expressed in magnetic units, a calibration of the magnetizing coil was performed. A search coil of 10 turns of No. 40 wire was wrapped on a 0.25 inch diameter insulator and inserted in the brass tube which forms the magnetizing coil core.

Using the induced voltage formula

$$e = -N \frac{d\theta}{dt} 10^{-8} \text{ volts} \tag{1}$$

and

$$e = \mu HA, \tag{2}$$

where μ is the permeability
H is the field intensity
A is the area of the search coil

thus,

$$\frac{dH}{dt} = -\frac{e}{\mu NA} 10^{8} \text{ oersteds/sec.} \tag{3}$$

where

$$\mu = 1, \; N = 10, \text{ and } A = .305 \text{ cm}^2$$

Therefore, equation (3) becomes

$$dH = - \frac{1.41\, E_{rms} \sin wt}{(10)\,(.305)} \; 10^8 \, dt \qquad (4)$$

Integrating equation (4) yields

$H_{max} = 122.6\, E_{rms}$ oersteds, when E_{rms} is measured in millivolts

A Ballantine VTVM was used to measure the induced voltage in the search coil. Fig. MRI-13142 shows H_{max} as a function of a-c magnetizing coil current.

2. Tests

Measurements of the VSWR, insertion loss, and attenuation of various ferromagnetic materials in a coaxial system have been initiated. To date, these measurements have been made on solid cylinders of varying length. The cylinders fill the brass tube and are butted against the center conductors of the testing unit. All of the cylinders are 0.285 inches in diameter.

The test frequency used has been 2000 mc/sec. and both a-c and d-c magnetizing coil current have been employed. The various ferromagnetic materials used are:

a) Polyiron D

b) Ferramic C

c) Ferramic G

d) Lavite F-4

Fig. MRI-13143 through Fig. MRI-13152 summarize the results of these tests. The variation in power level (attenuation) is given as a function of both a-c and d-c magnetizing coil current for a frequency of 2000 mc/sec.

3. Projected Program

The data summarized by the appended graphs is to be supplemented by extension of the frequency range to 4000 mc/sec. After complete data for the solid cylinder is obtained, the geometry will be changed to that of a recessed cylinder and the tests repeated.

C. Phase-Shift Measurements

Components of the phase measuring bridge system are being constructed for line size 1-1/2" x 3/4" in order to evaluate the phase response of the 1-1/2" x 3/4" waveguide attenuator. In this regard, a standard phase-shifter is being developed which comprises of a dielectric plate tapered at each end. The casing being used is the one designed for the 1-1/2" x 3/4" attenuator. However, its length may be longer than 8-1/2 inches depending upon the length of the optimum dielectric plate to be designed.

Two plates were tried having taper lengths of 2" and 3". The phase responses shown by Figs. MRI-13157 and MRI-13159 indicate magnitudes which are acceptable. However, the VSWR responses illustrated by Figs. MRI-13158 and MRI-13160 are rather high at the wavelength of 3.66 cm. Longer tapers may remedy this situation.

D. Fixed Attenuators for 3/8" Coaxial Line

In connection with the measurement of the attenuation values of the tenth decibel series film attenuators, a program, in addition to that described in Report R-222.16-52, PIB-167.16, has been actuated. This program, it will be recalled, is based on the theory that the attenuation of a low loss quadripole can readily be determined from a knowledge of the standing wave ratio of the unknown component terminated in a short circuit. The step-by-step procedure includes the determination of high standing wave ratios at discrete points in the slotted section by measurement of the displacement between the double power points above the minimum, from which the attenuation can be calculated. The arrangement of equipment for this measurement is shown in Fig. MRI-12410.

During this past interval, measurements were made utilizing the recently completed precision drive 3/8" slotted section designed to operate down to 1000 mc/sec. In addition, the merits of both contacting and non-contacting 7/8" coaxial shorting plungers were studied. The VSWR's of both these types were of comparable magnitude and varied between values of 20 and 40 in the frequency range from 1000 to 4000 mc/sec.

Of severe importance to this measurement system are:

a) The losses in the walls and inner conductor of the slotted section.

b) The losses in the walls and inner conductor of the coaxial shorting plunger.

c) The losses in the walls of the short per se.

d) The power that leaks past the shorting plunger.

Since these losses are included in the measurement of the sample attenuator, the system must be calibrated for each frequency so that these losses may be subtracted from the total result. Preliminary measurements made at 4000 mc/sec. indicate that the losses in the 3/8" slotted section intended for use in the measurement system were of the order of 0.1 db per 1.5 inch of slotted section. A 7/8" slotted section calibrated in a similar manner showed losses of the same order of magnitude. These values are in substantial agreement with values calculated from standard formulae in the literature. The losses in the walls of the 7/8" coaxial shorting plunger were measured to be of the order of 0.01 db per 1.5 inches of guide and, again, are in substantial agreement with calculated values. (The losses in the plunger proper and in the leakage component have not as yet been determined.) As a consequence, it is easily conceivable that the losses in the system are in excess of the attenuation values of the extremely low valued db attenuators (e.g., the 0.1 db and 0.2 db attenuators), and are of the same order of magnitude as the higher tenth db units. Thus, precise determination of these losses is required in order that the true attenuation value of the sample be not masked by the losses.

A further perturbating factor is the fact that the shorting plunger, because of the required drive, is made in 7/8" coaxial line while the attenuator units are designed for 3/8" line, thus, introducing a line size change into the test system which complicates the evaluation of the system losses. Measurements are currently being made to determine accurately the broadband characteristics of the shorting plungers and the system components necessary to the precision measurement system.

Concurrent with this program, an alternative measurement system developed at MRI, is being utilized which is based on the measurement of absolute power delivered to a bolometer element which serves as one arm of a Wheatstone Bridge. The basic circuit arrangement is shown in Fig. MRI-12642. With the bolometer as one arm of the Wheatstone Bridge, the bridge is initially balanced with a bridge current I_o. The microwave power is then applied to the bolometer and the bridge is kept in balance by increasing R (the decade resistor), which decreases the bias power. The RF power is then said to be equal to the differences in bias power and if the final bridge current is I_1, it can be shown that

$$P_{RF} = P_{bias} = (I_o^2 - I_1^2) \frac{R_b}{4}$$

where R_b = the bolometer resistance at balance. It is felt that the bridge will serve not only to measure with a high degree of accuracy the attenuation value of the low db units but will, in addition, be applicable to measurements of most of the other higher attenuator units. Thus, this measurement technique will serve to corroborate data measured by other techniques. The sources of error inherent to the system are dependent basically on the accurate determination of the difference in resistance required to restore balance and the initial bias current reading. Other factors influencing the measurement include the stability of both the d-c and r-f power sources and the sensitivity of the detectors. These will be discussed in detail in the report for the next interval.

In the last progress report, VSWR and attenuation characteristics of (an average of six each) 0.8 db and 9.0 db were presented, wherein it was indicated that the VSWR values approached prohibitively high values above frequencies of 2500 and 3000 mc/sec., respectively. Final assembly of the chimney type attenuators (which include integral values of attenuation from 3 db to 9 db) were deferred pending modification of the internal structure in an effort to extend the working range of these attenuators. First results of this redesign are shown listed in Table I, and a comparison plot is shown in Fig. MRI-13154 for two chimney units, an 0.8 db and a nominal 8.0 db attenuator. The data indicates a marked decrease in the VSWR at the high frequency end of the spectrum. It is anticipated that additional minor modifications will further improve the VSWR response and decrease the attenuation excursion at the higher frequencies.

Consideration is also being given to the final packaging of the decade attenuator and, in particular, to the design of a quick connect-disconnect coaxial connector or equivalent contacting arrangement. These will be discussed in detail in the report for the next interval.

E. Probe Attenuators

We have been informed by representatives of the New York Naval Shipyards that they have been asked to cooperate with us in the high (r-f) power testing of the probe attenuator units. A schedule is being arranged which will be mutually satisfactory and will not interfere with the operation of the Materials Laboratory there.

1. 1-5/8" Coaxial Probe Attenuator

Evaluation of the performance characteristics of the 1-5/8" coaxial probe attenuator (including input standing wave pattern and probe decoupling and specification of the final design) have been delayed pending completion of the prototype unit now under construction.

2. L-Band Probe Attenuator

Measurements are currently being made to determine the optimum probe depth for the L-band probe attenuator unit shown sketched in Fig. MRI-13155. The attenuation measuring scheme utilized is a standard r-f substitution method utilizing a calibrated attenuator unit in the r-f circuit. The basic arrangement of equipment and method of measurement is outlined in Fig. MRI-13156. Inasmuch as L-band systems are generally high peak power systems, it is felt that a probe line decoupling of 60 db down from the main guide is appropriate.

III. Program for the Next Period

1. Improvement of 7/8" variable coaxial attenuator by reducing capacitive reactance.

2. Frequency extension of magnetic attenuator under development and determination of the influence of specimen geometry on performance.

3. Design of 1-1/2" x 3/4" standard phase shifter and assembly of overall system.

4. Attenuation and VSWR measurements of fixed attenuators for 3/8" coaxial line.

5. Overall design of mechanism for realizing a 3/8" decade attenuator.

6. Evaluation of performance of 1-5/8" coaxial probe attenuator.

7. Determination of optimum probe depth of the L-band probe attenuator.

TABLE I

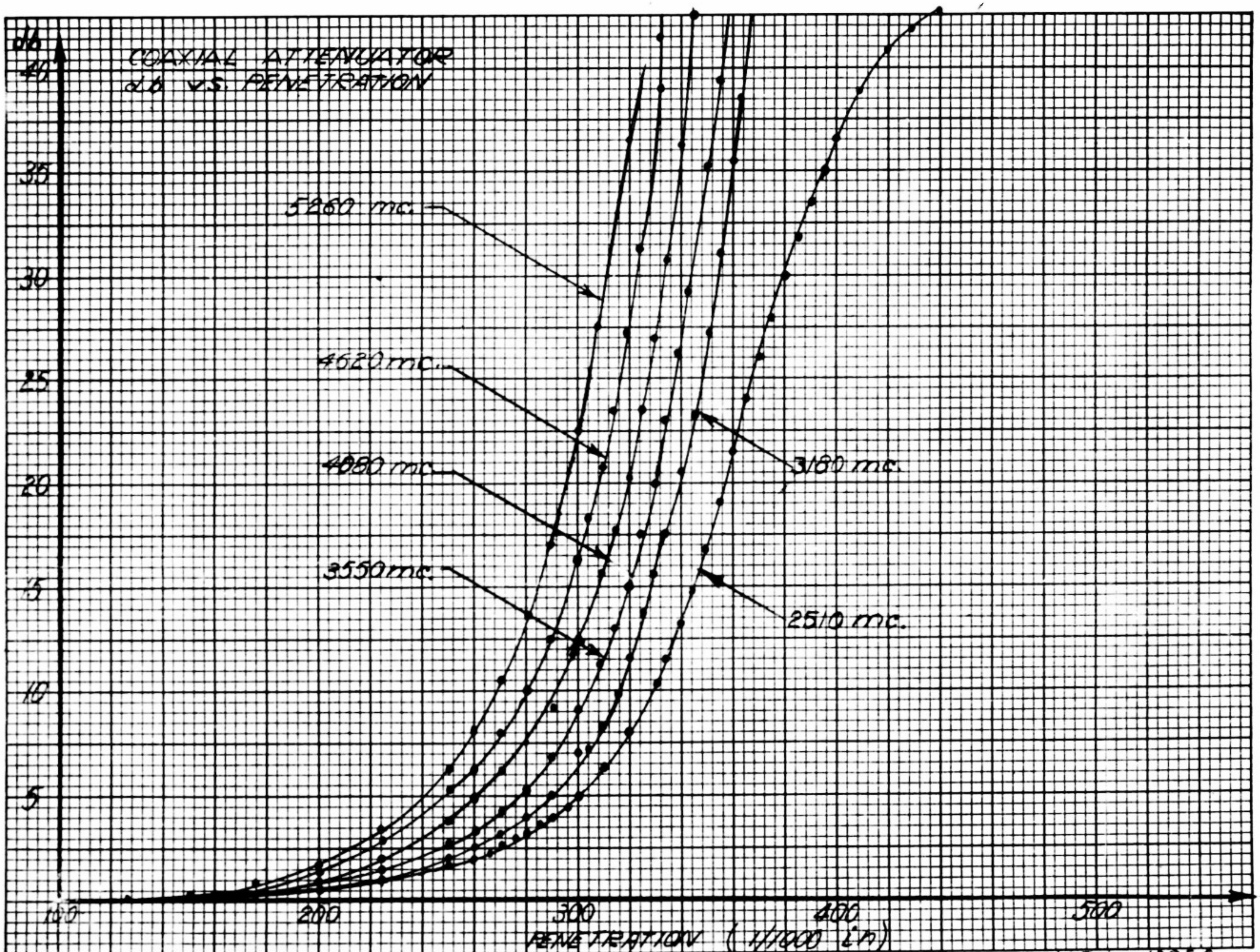
CHARACTERISTICS OF 0.8db AND 8.0db NOMINAL
MODIFIED CHIMNEY-TYPE ATTENUATORS

VSWR
FREQUENCY IN MEGACYCLES PER SECOND

No. db	1000	1500	2000	2500	3000	3500	4000
0.8	1.06	1.06	1.19	1.16	1.16	1.19	1.23
8.0	1.04	1.09	1.11	1.22	1.22	1.34	1.43

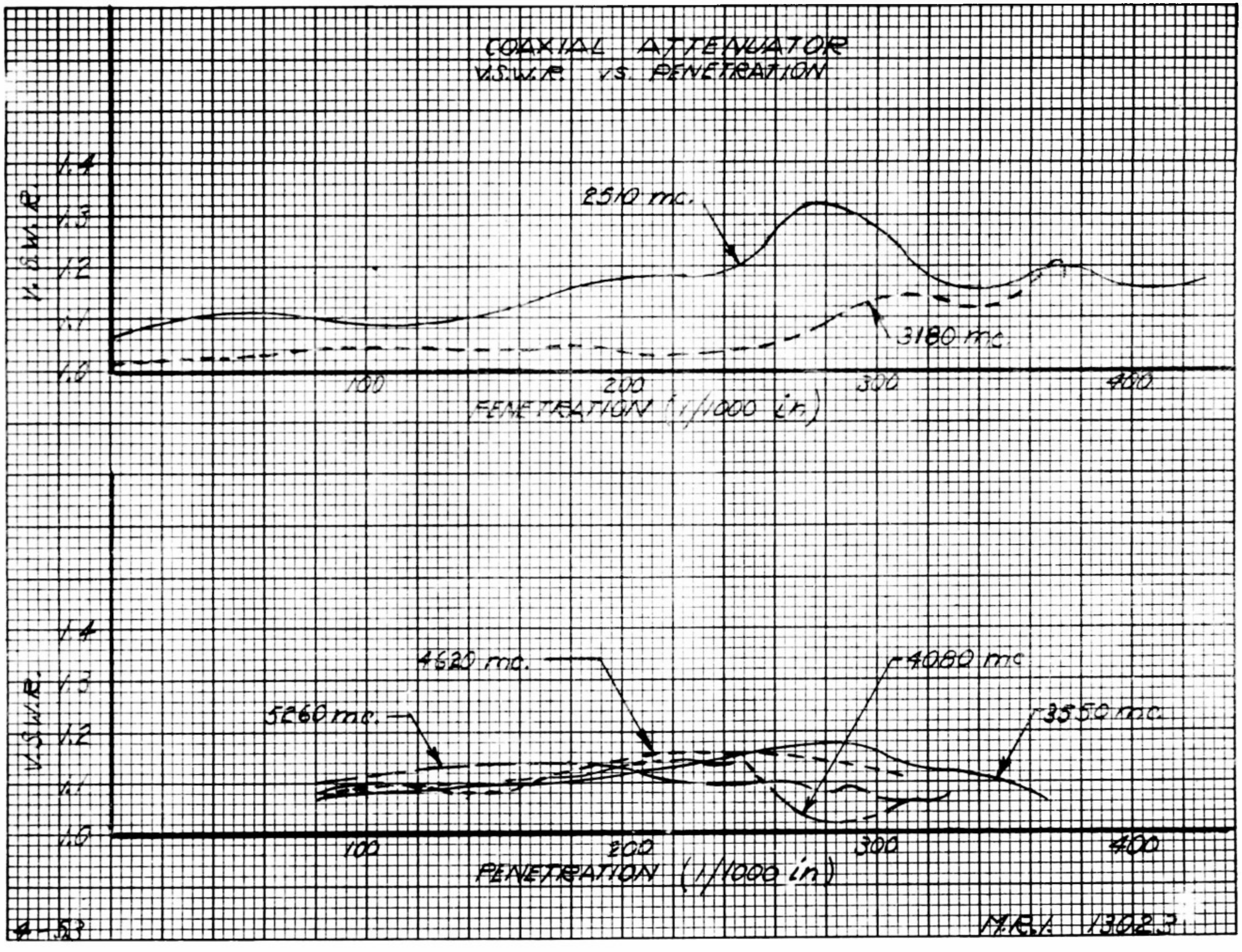
ATTENUATION
FREQUENCY IN MEGACYCLES PER SECOND

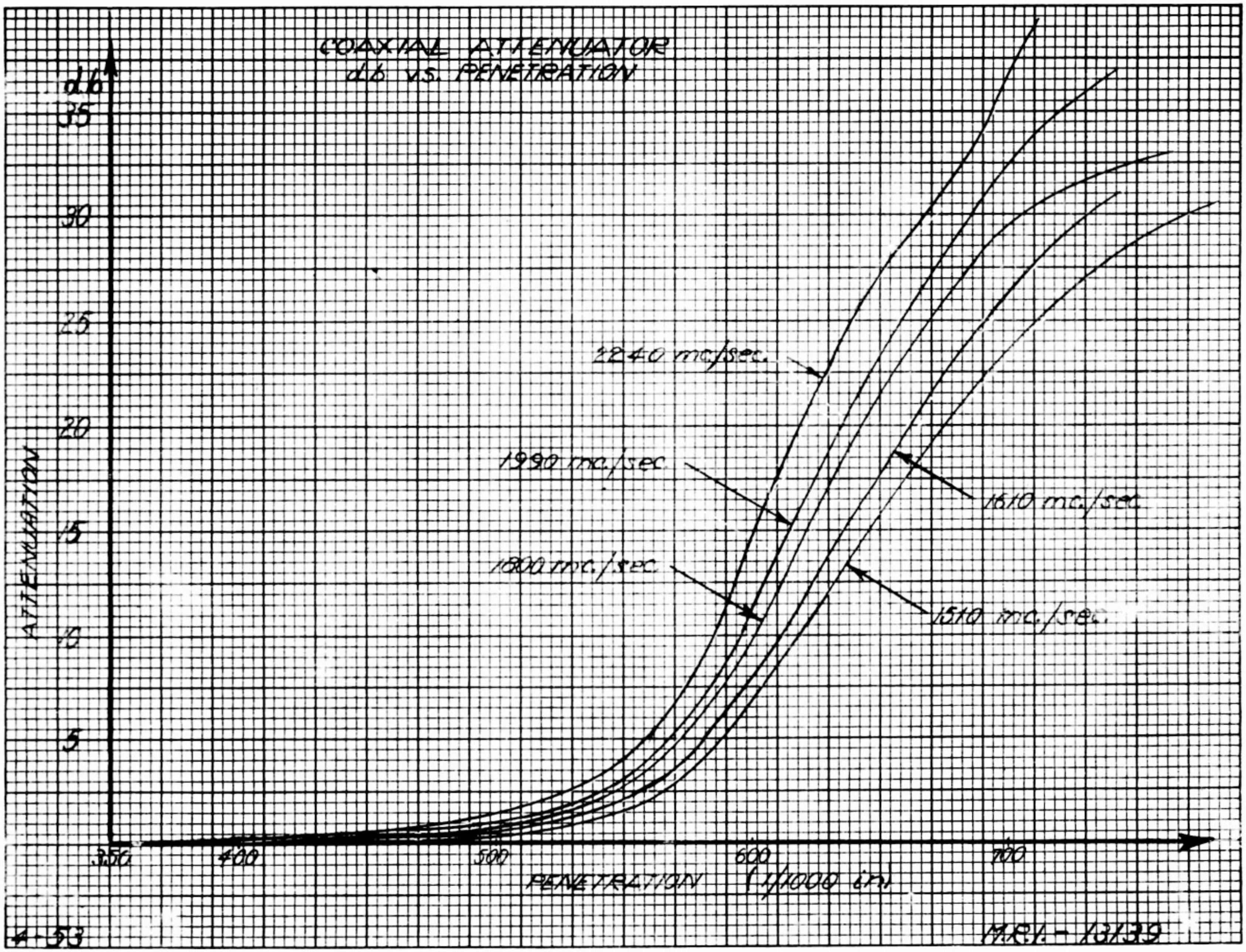
No. db	CALC. d-c	1000	1500	2000	2500	3000	3500	4000
0.8	0.83	1.0	1.15	1.3	1.27	1.2	1.2	1.3
8.0	7.3	7.35	7.0	6.75	7.1	7.68	8.88	10.8



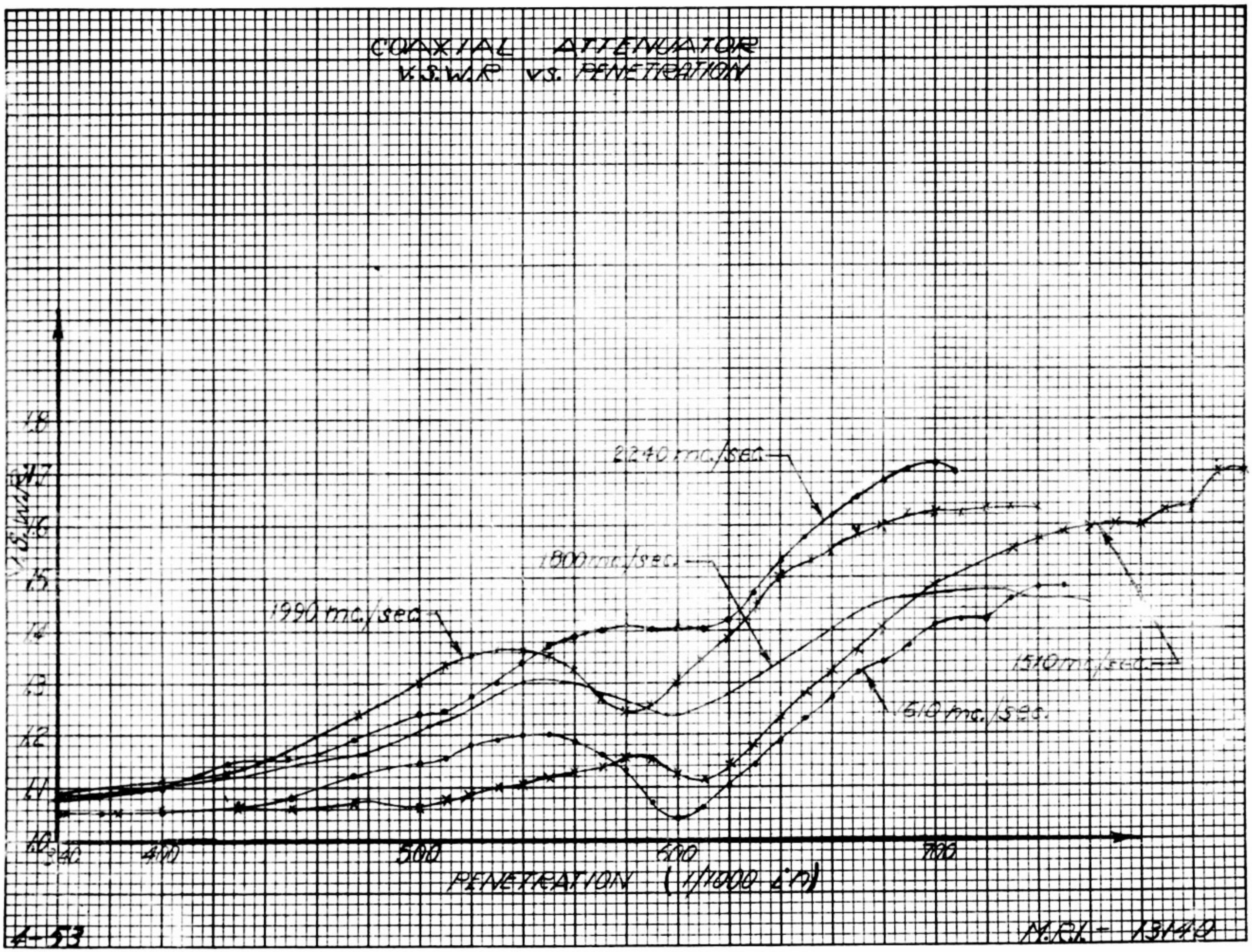
4-53

M.R.I. - 13022

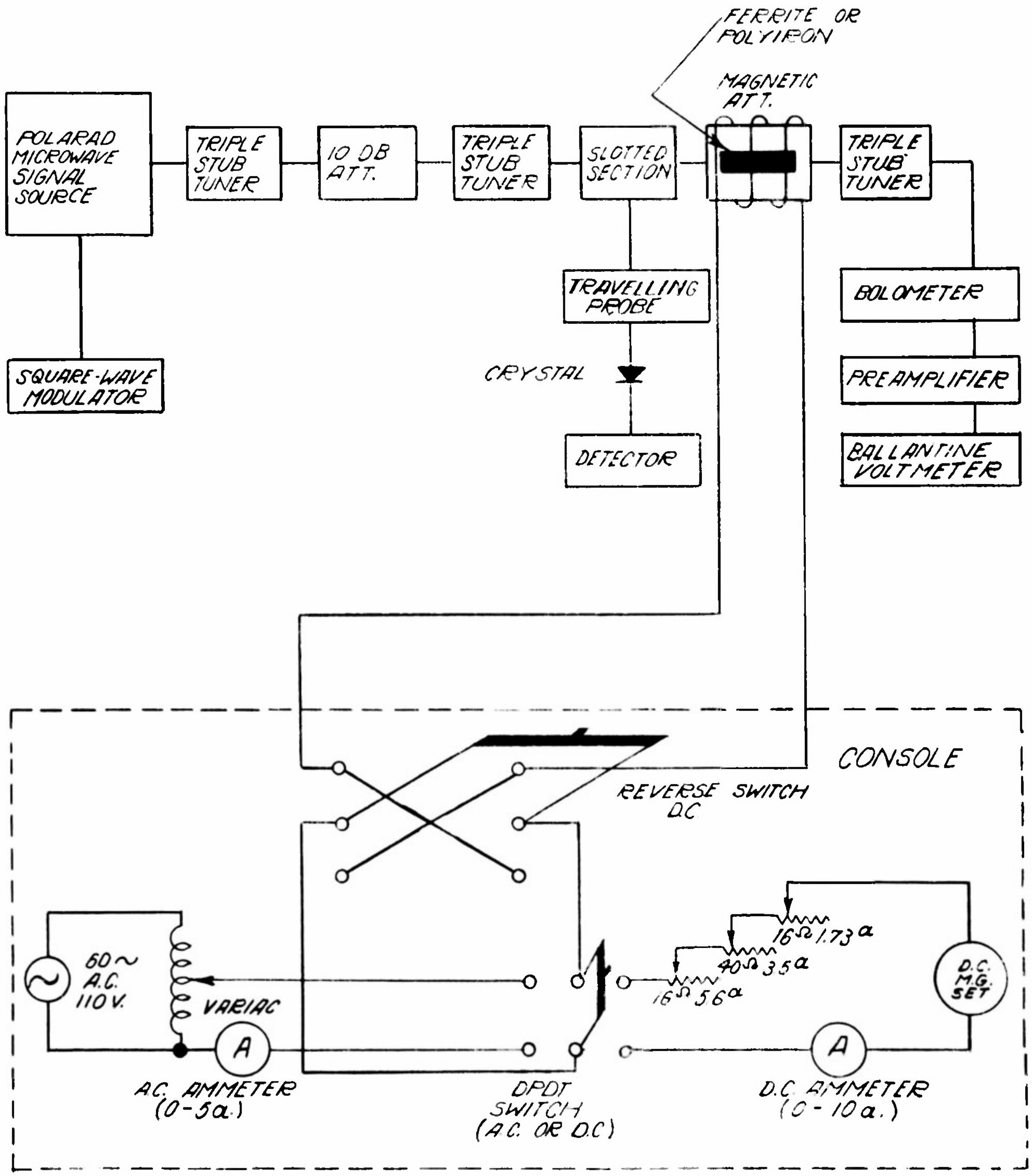

COAXIAL ATTENUATOR
V.S.W.R. VS. PENETRATION
V.S.W.R.
1.4
1.3
1.2
1.1
1.0
2510 mc.
3180 mc.
100
200
300
400
PENETRATION (1/1000 in.)
V.S.W.R.
1.4
1.3
1.2
1.1
1.0
4620 mc.
4080 mc.
5260 mc.
3550 mc.
100
200
300
400
PENETRATION (1/1000 in.)
4-53
M.R.I. 13023

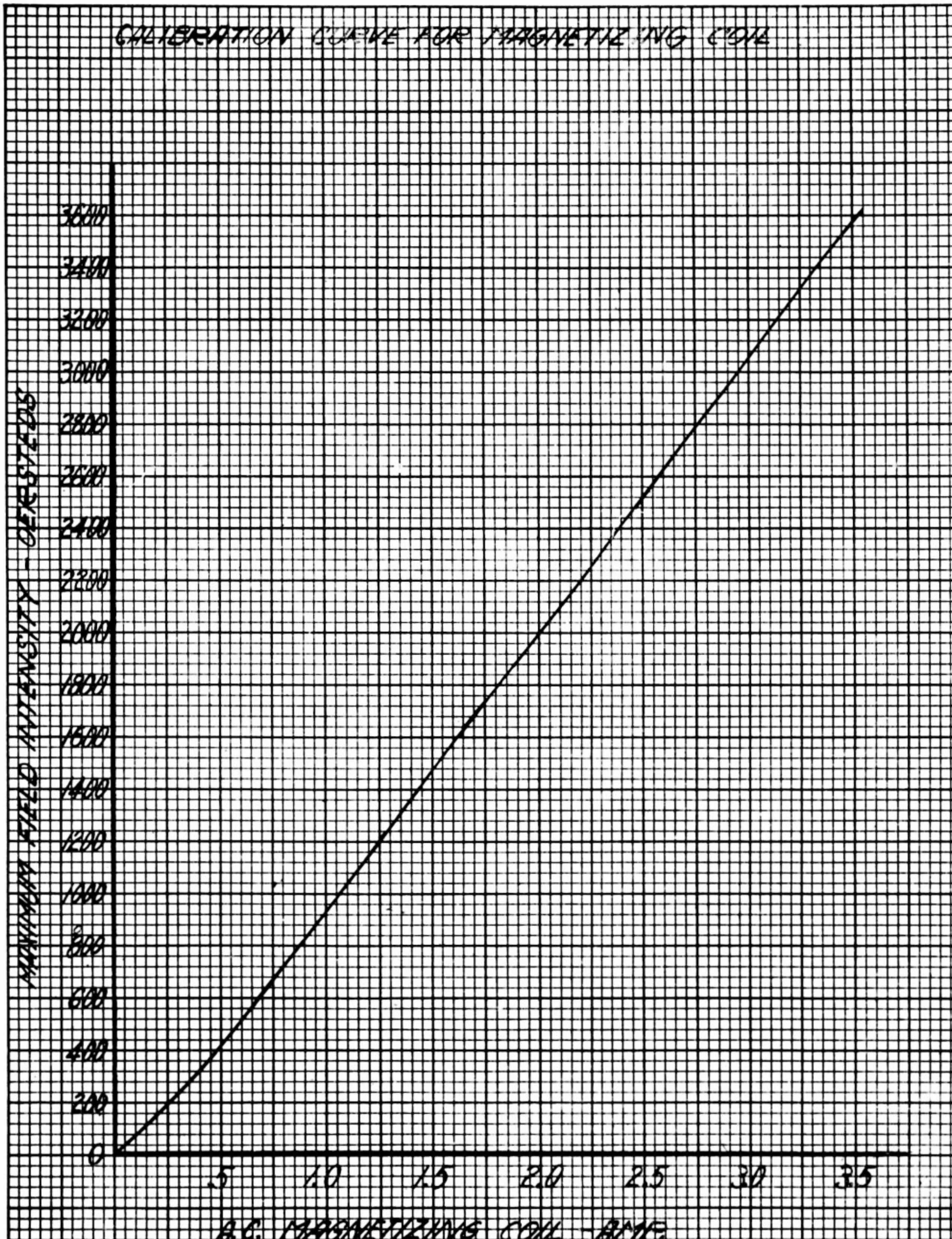


COAXIAL ATTENUATOR
db vs. PENETRATION
db
35
30
25
20
15
10
5
ATTENUATION
350
400
500
600
700
PENETRATION (1/1000 in.)
2240 mc/sec.
1990 mc./sec
1800 mc./sec
1610 mc./sec
1510 mc./sec.
4-53
M.R.I. - 13139


COAXIAL ATTENUATOR
V.S.W.R. vs. PENETRATION
2240 mc./sec.
1800 mc./sec.
1990 mc./sec.
1510 mc./sec.
1610 mc./sec.
V.S.W.R.
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
340
400
500
600
700
PENETRATION (1/1000 in)
4-53
M.R.L. - 13149

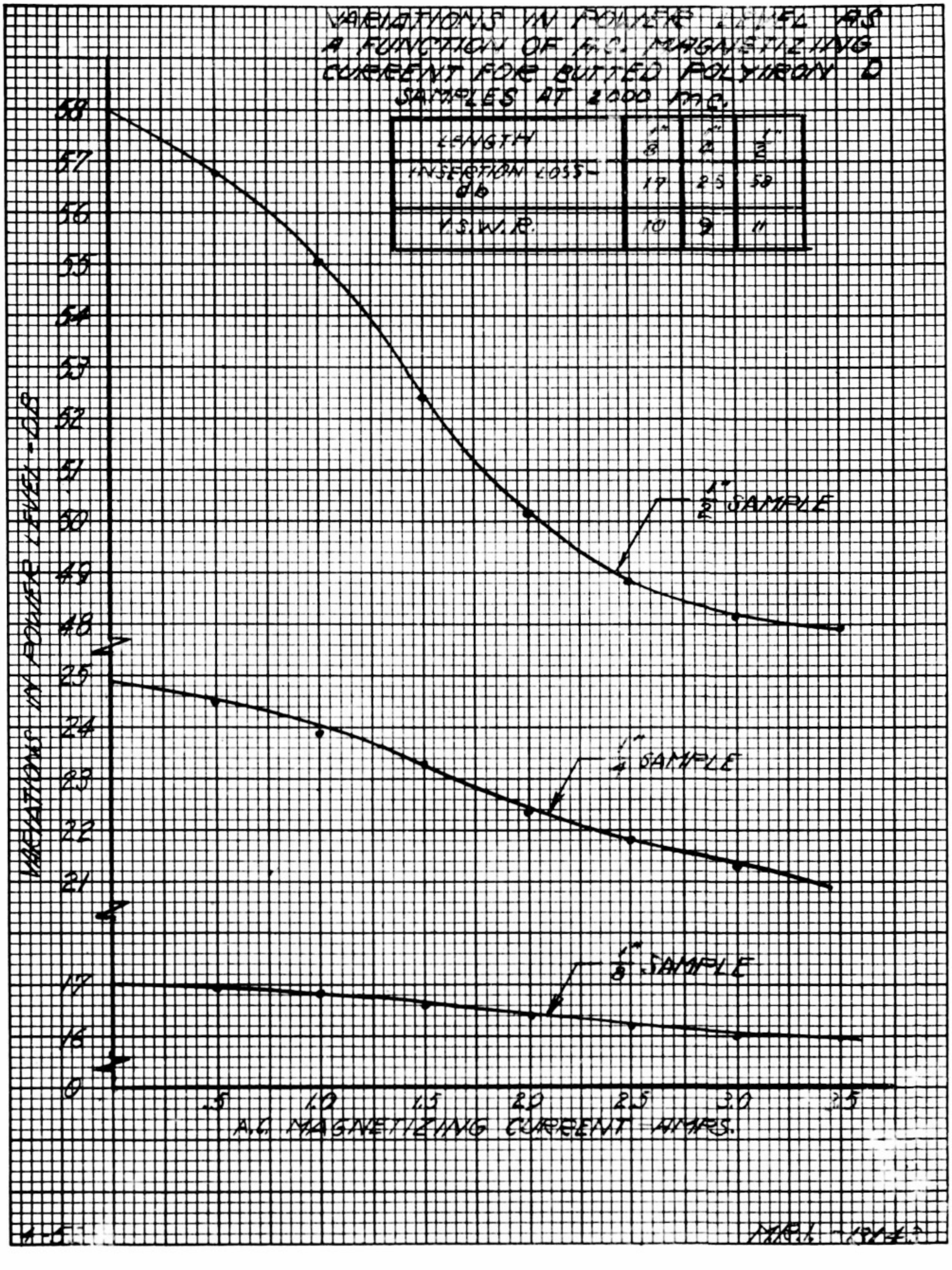
CIRCUIT FOR MEASURING V.S.W.R., INSERTION LOSS, AND VARIATION IN POWER LEVEL AS A FUNCTION OF A.C. & D.C. MAGNETIZING CURRENT FOR FERROMAGNETIC MATERIALS IN COAXIAL

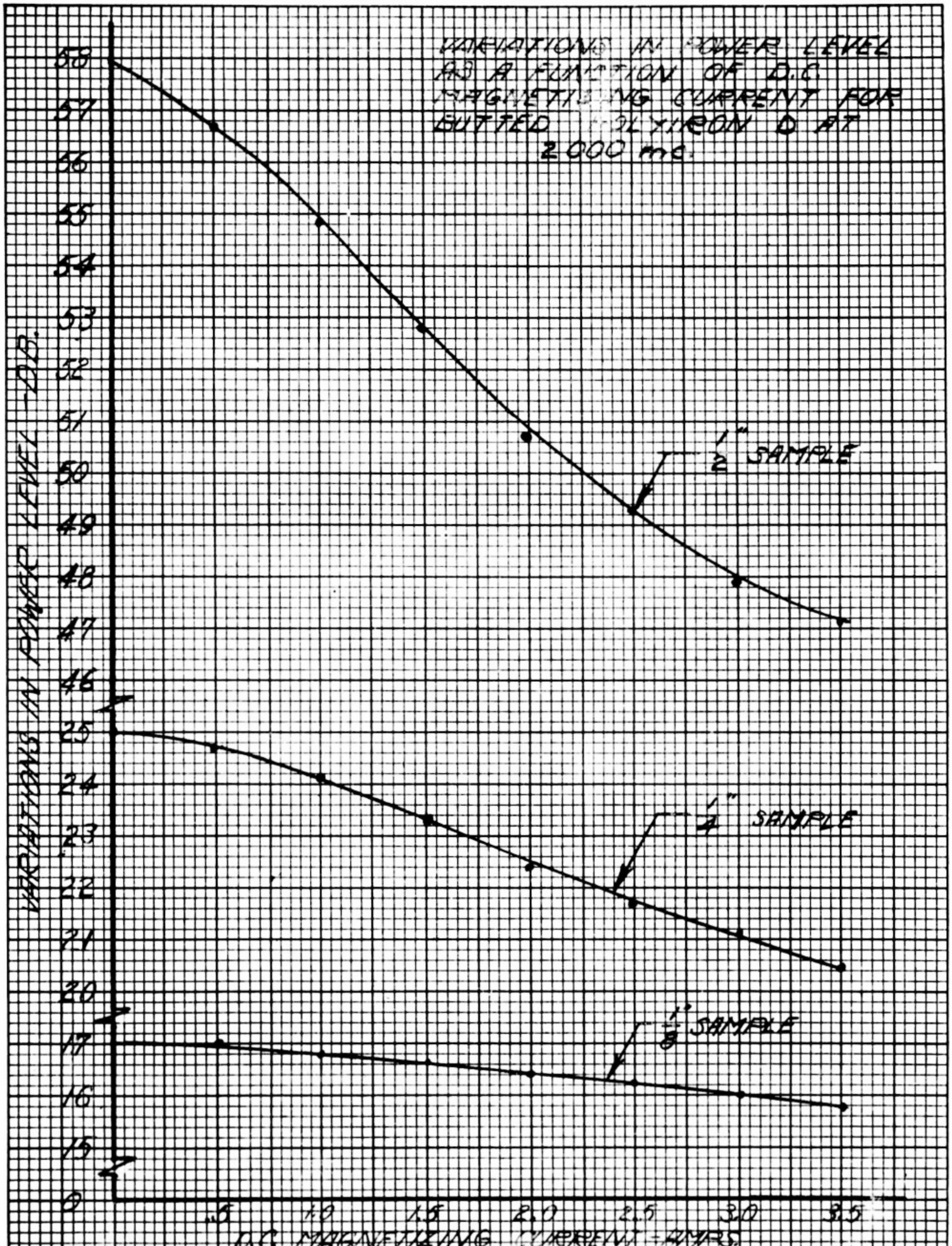




A-53

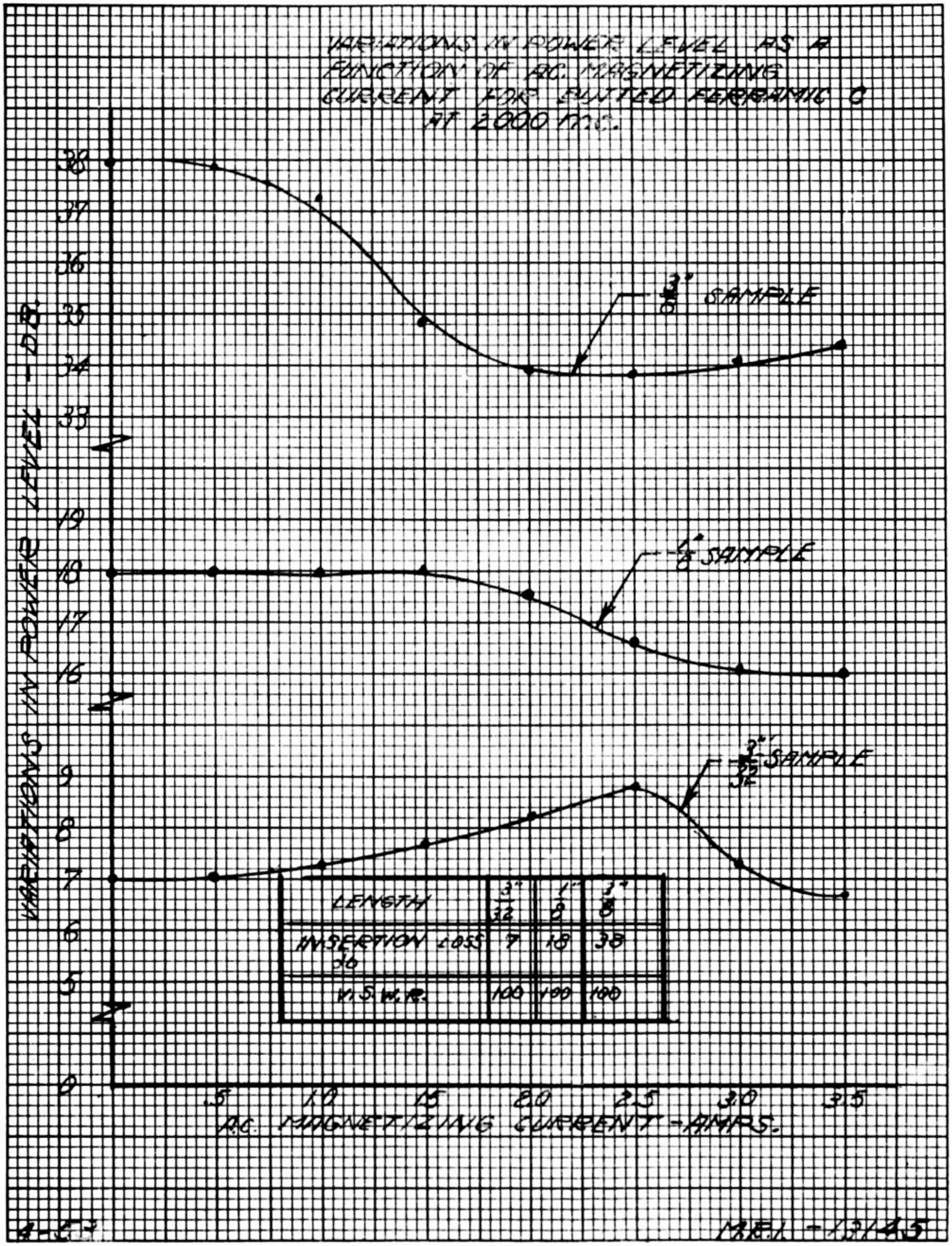
M.R.L. 13142


VARIATIONS IN POWER LEVEL AS A FUNCTION OF A.C. MAGNETIZING CURRENT FOR BUTTED POLYIRON D SAMPLES AT 2000 MC.
LENGTH
INSERTION LOSS—db
V.S.W.R.
1/8"
1/4"
1/2"
17
25
58
10
9
11
1/2" SAMPLE
1/4" SAMPLE
1/8" SAMPLE
VARIATIONS IN POWER LEVEL - DB
A.C. MAGNETIZING CURRENT - AMPS.
0
16
17
21
22
23
24
25
48
49
50
51
52
53
54
55
56
57
58
.5
1.0
1.5
2.0
2.5
3.0
3.5

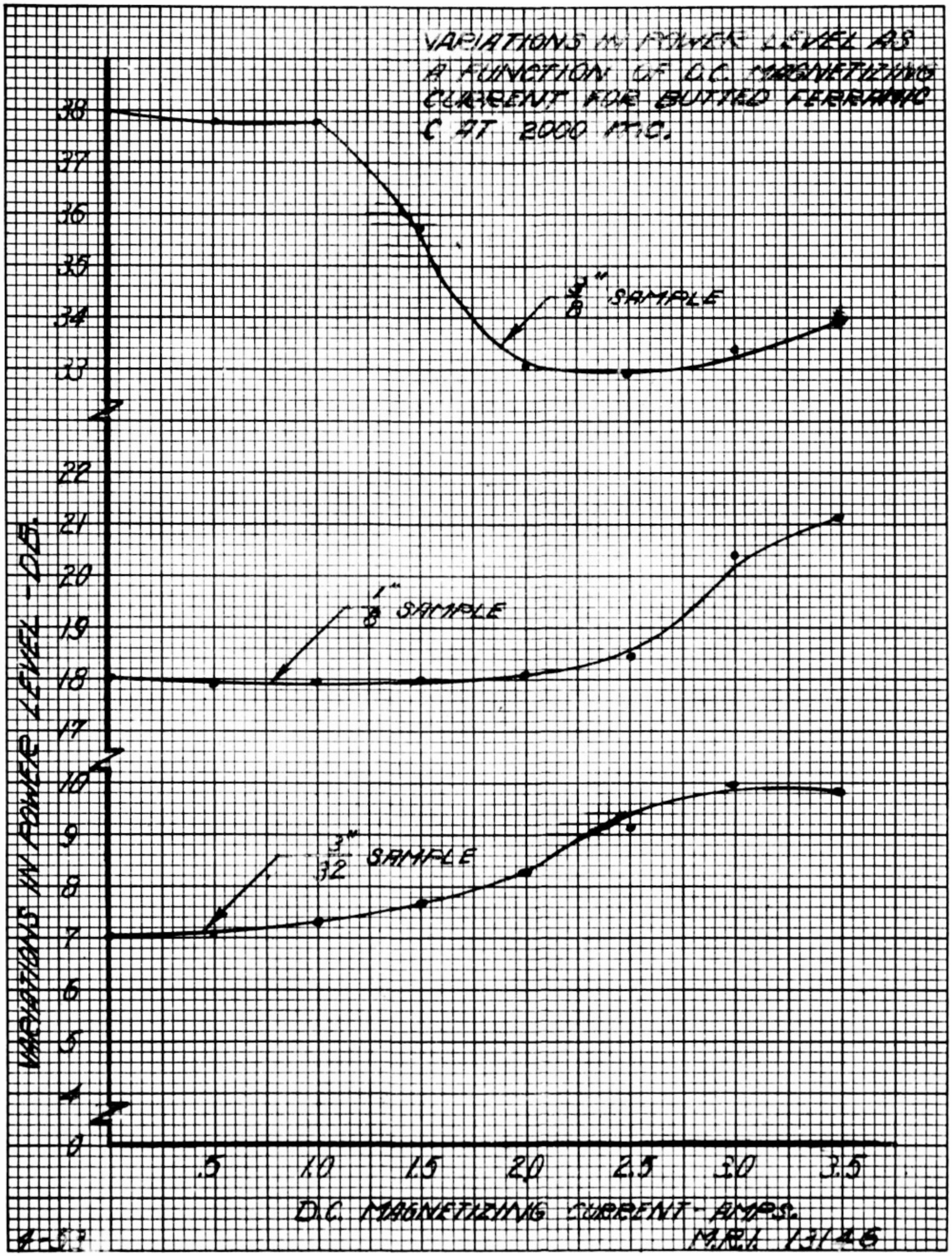


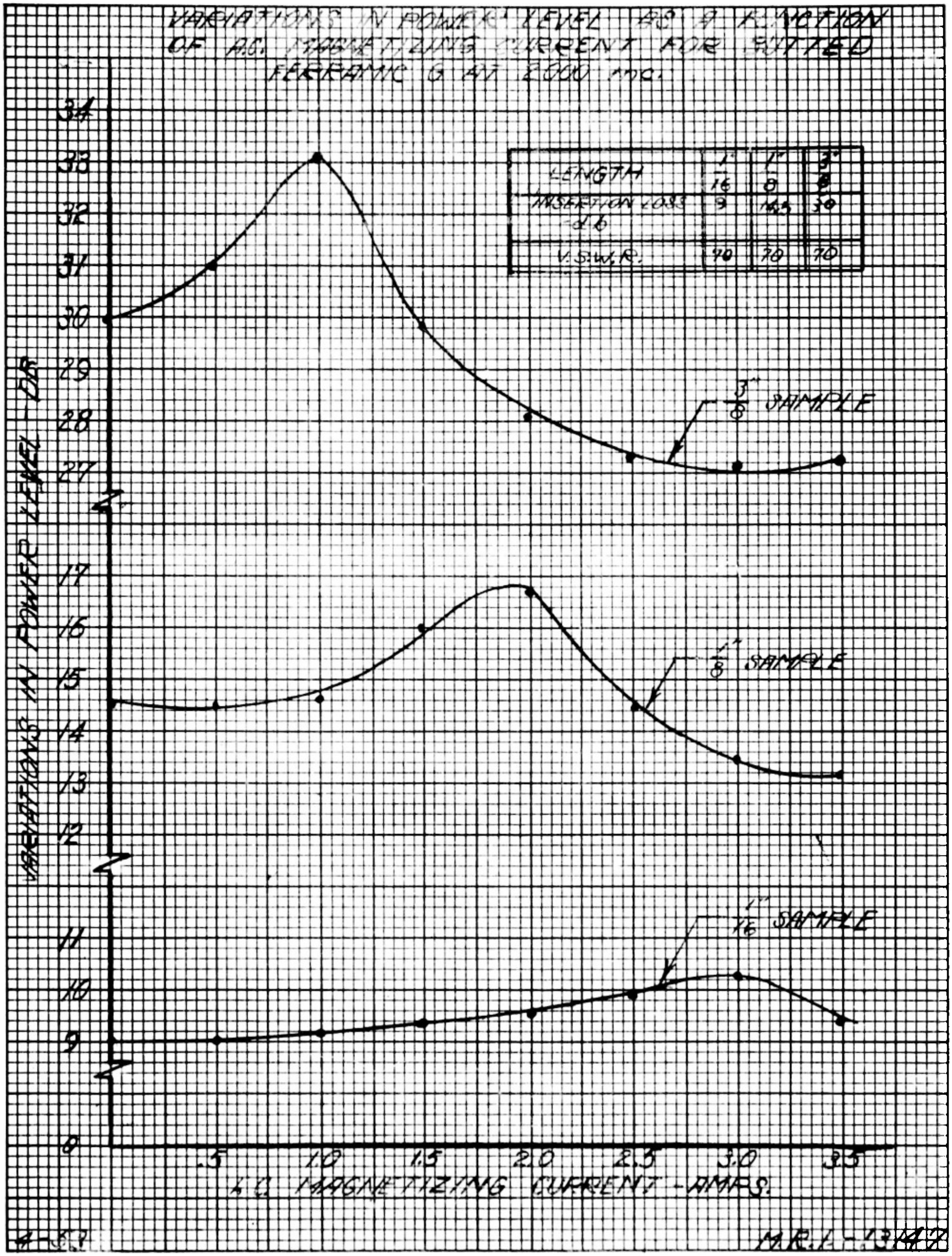
4-53

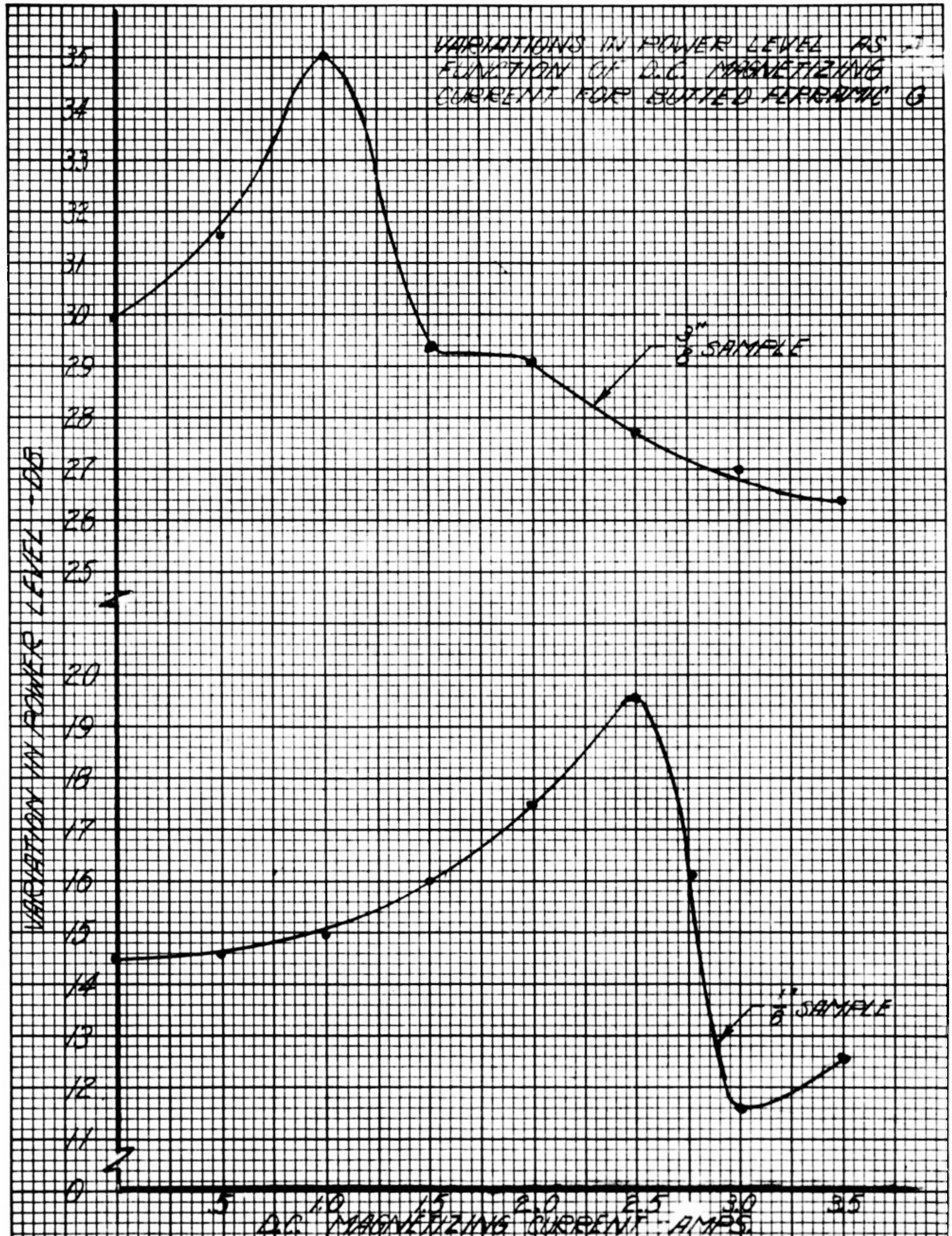
M.R.I. -13144



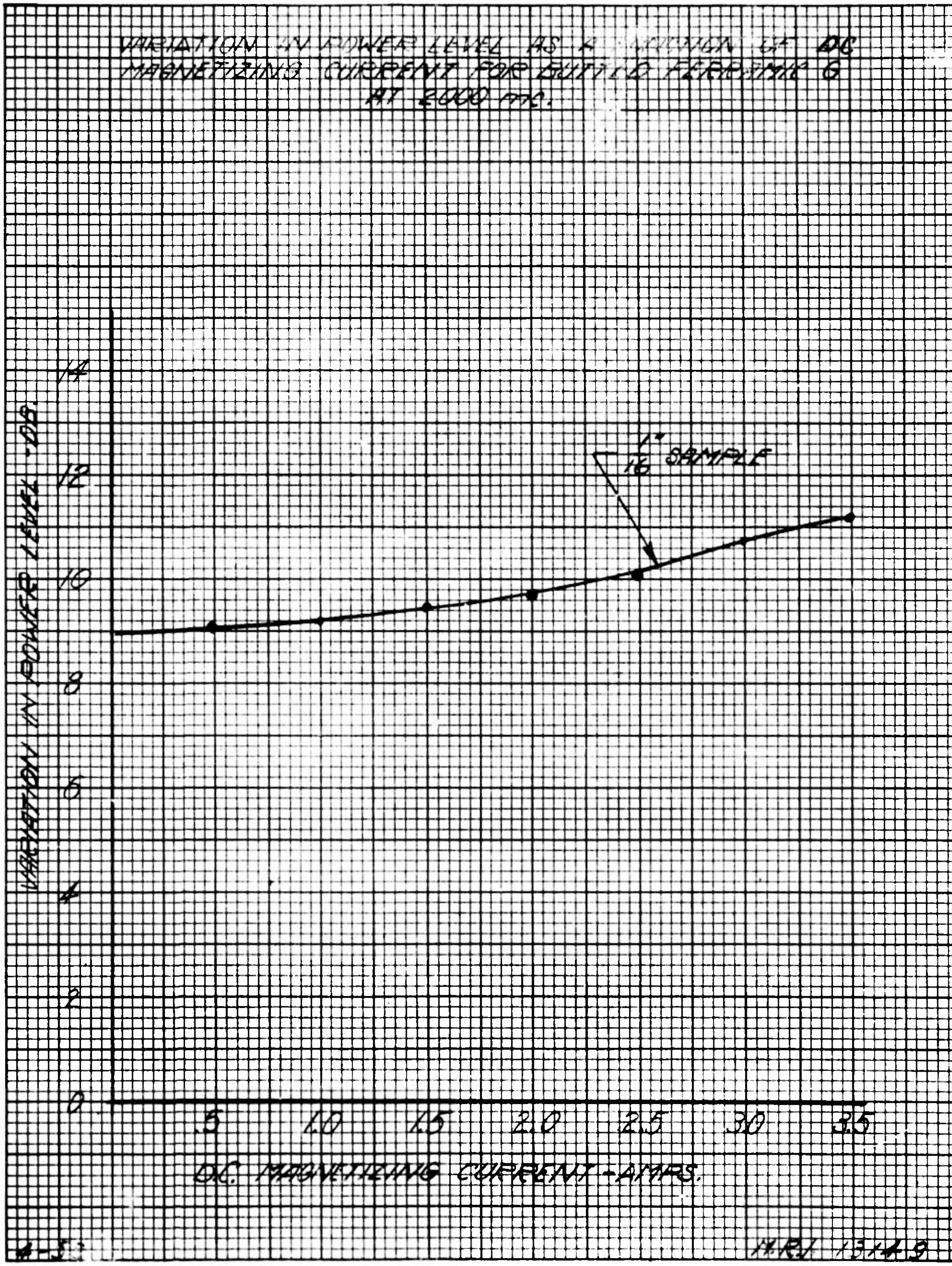
LENGTH	3/32"	1/8"	3/8"
INSERTION LOSS DB	7	18	38
V.S.W.R.	1.00	1.00	1.00

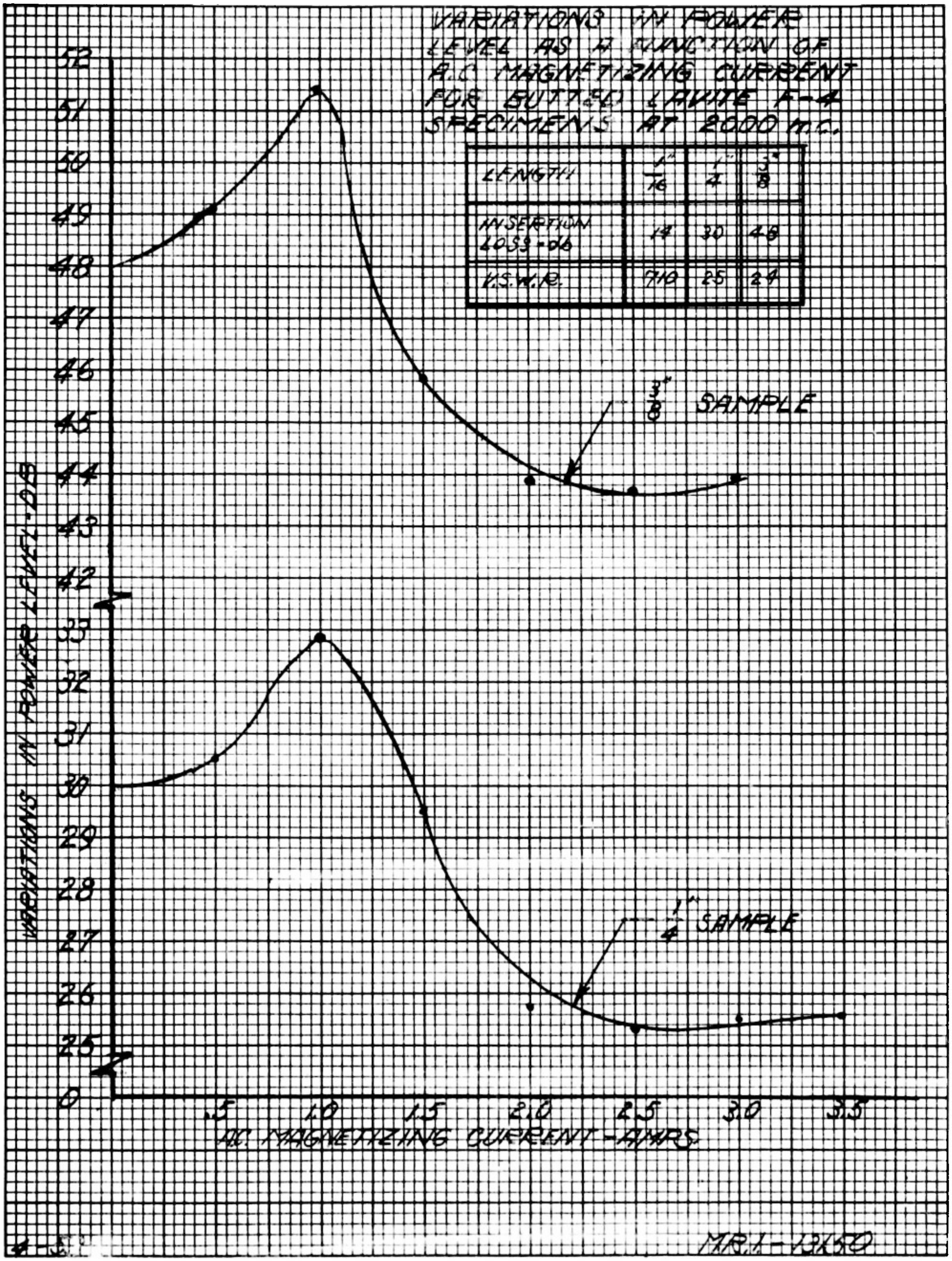

VARIATIONS IN POWER LEVEL AS A FUNCTION OF D.C. MAGNETIZING CURRENT FOR BUTTED FERRAMIC C AT 2000 M.C.
VARIATIONS IN POWER LEVEL - DB.
D.C. MAGNETIZING CURRENT - AMPS.
1/8" SAMPLE
3/32" SAMPLE
38
37
36
35
34
33
22
21
20
19
18
17
10
9
8
7
6
5
4
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
M.R.I. 13146


VARIATIONS IN POWER LEVEL AS A FUNCTION
OF A.C. MAGNETIZING CURRENT FOR POTTED
FERRAMIC G AT 2000 mc.
LENGTH
1"/16
1"/8
3"/8
INSERTION LOSS - db
9
14.5
30
V.S.W.R.
70
70
70
3"/8 SAMPLE
1"/8 SAMPLE
1"/16 SAMPLE
VARIATIONS IN POWER LEVEL - DB
34
33
32
31
30
29
28
27
17
16
15
14
13
12
11
10
9
8
.5
1.0
1.5
2.0
2.5
3.0
3.5
A.C. MAGNETIZING CURRENT - AMPS.
4-53
M.R.I.-1347


VARIATIONS IN POWER LEVEL AS A FUNCTION OF D.C. MAGNETIZING CURRENT FOR BUTTED FERRAMIC G
3/8" SAMPLE
1/8" SAMPLE
VARIATION IN POWER LEVEL - DB.
D.C. MAGNETIZING CURRENT AMPS.
35
34
33
32
31
30
29
28
27
26
25
20
19
18
17
16
15
14
13
12
11
0
.5
1.0
1.5
2.0
2.5
3.0
3.5

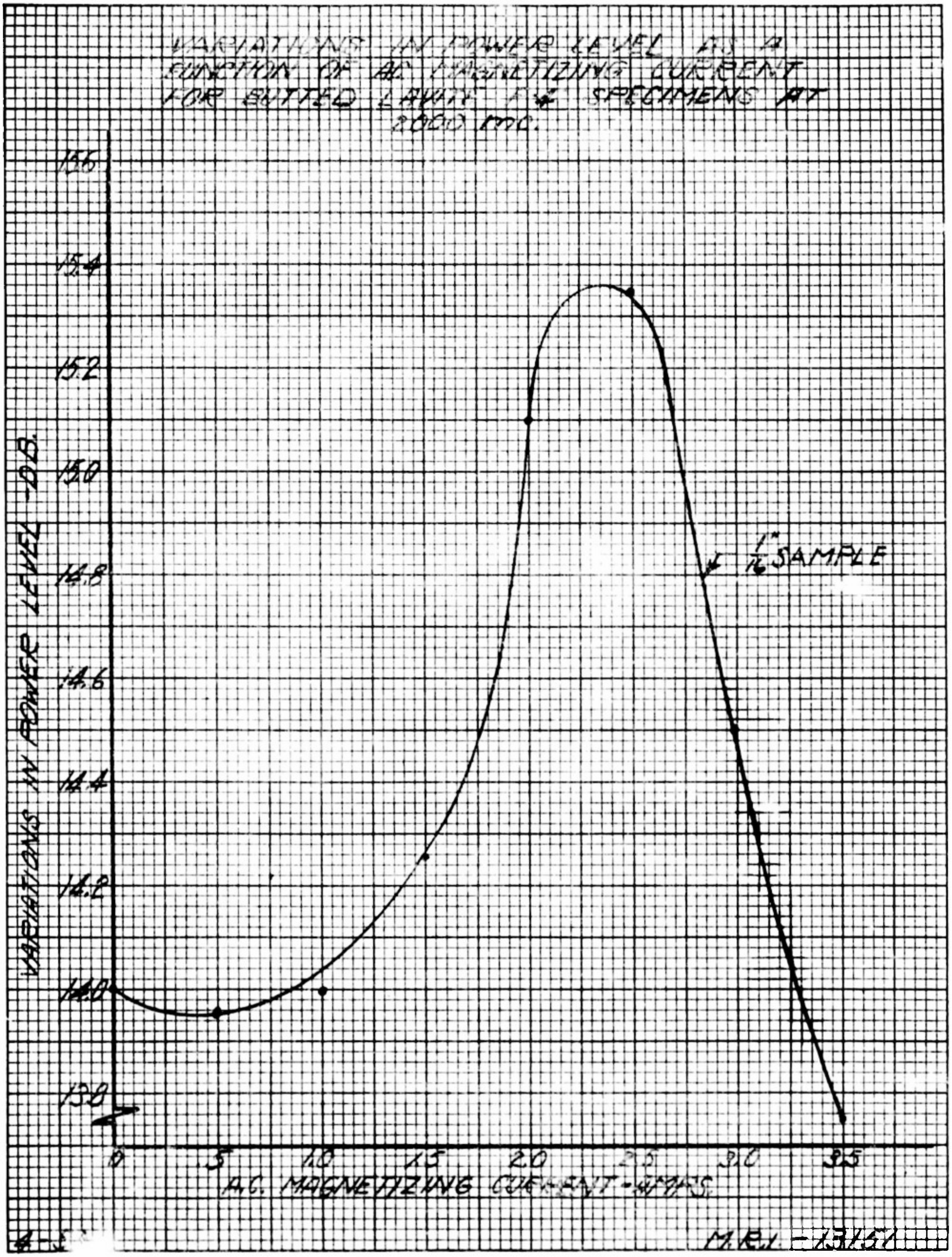
M.R.I. 13148

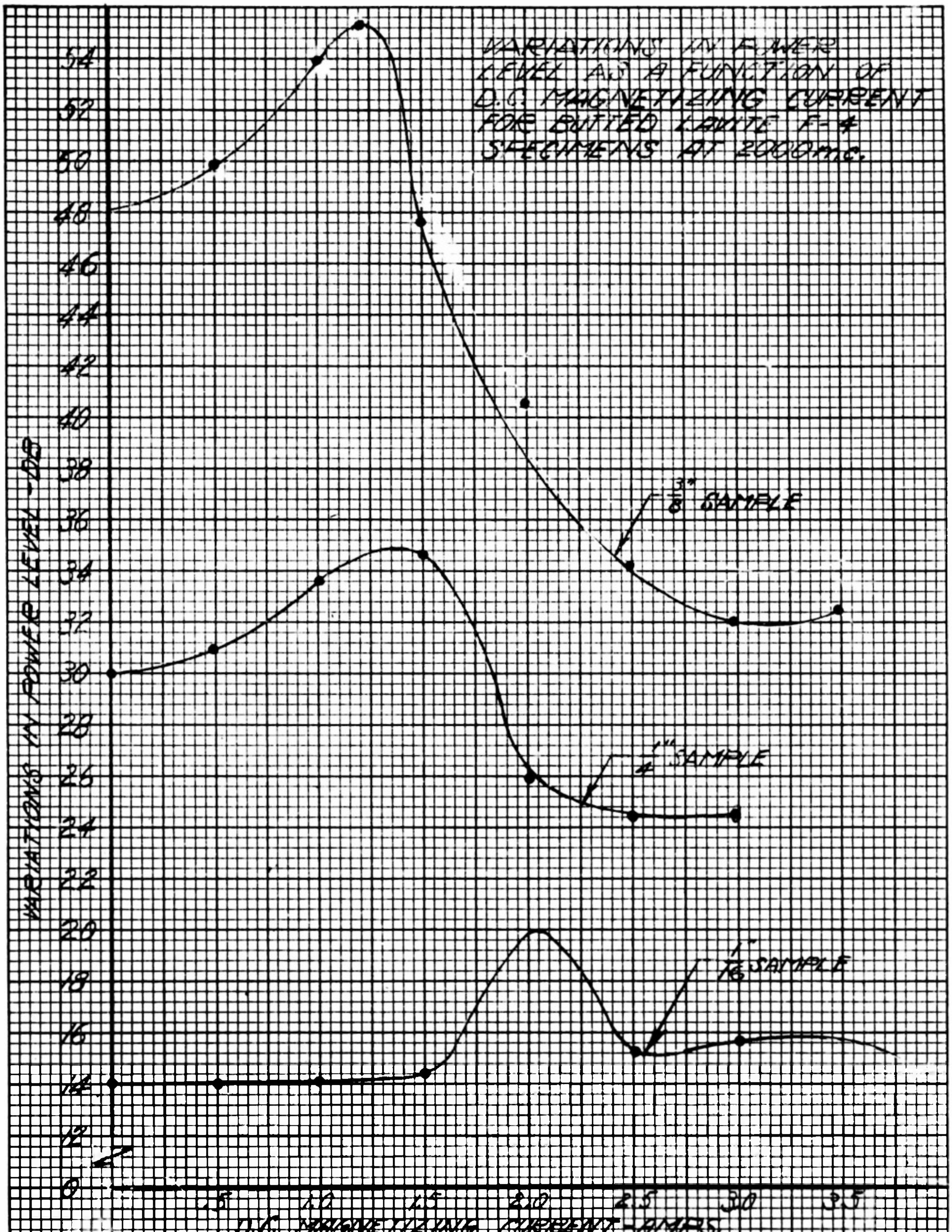

VARIATION IN POWER LEVEL AS A FUNCTION OF DC
MAGNETIZING CURRENT FOR BUTTED FERRAMIC G
AT 2000 MC.
VARIATION IN POWER LEVEL - DB.
14
12
10
8
6
4
2
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
1/16" SAMPLE
D.C. MAGNETIZING CURRENT - AMPS.
H.R.I. 1314-9



VARIATIONS IN POWER LEVEL AS A FUNCTION OF A.C. MAGNETIZING CURRENT FOR BUTTED LAVITE F-4 SPECIMENS AT 2000 MC.
LENGTH 1"/16 1"/4 3"/8
INSERTION LOSS-DB 14 30 46
V.S.W.R. 7.0 2.5 2.4
3"/8 SAMPLE
1"/4 SAMPLE
VARIATIONS IN POWER LEVEL-DB
52
51
50
49
48
47
46
45
44
43
42
33
32
31
30
29
28
27
26
25
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
AC MAGNETIZING CURRENT-AMPS

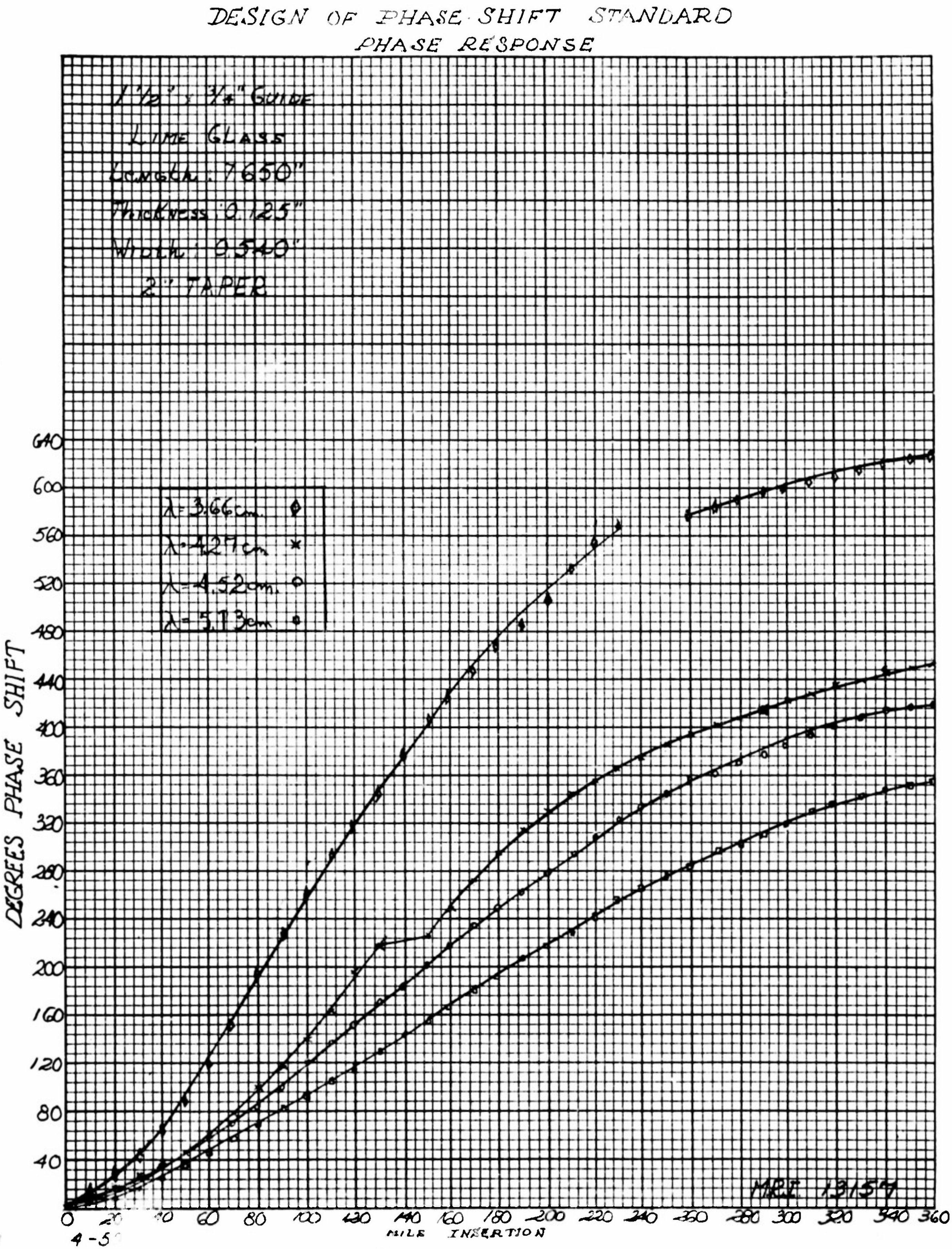
MR.I-13150


VARIATIONS IN POWER LEVEL AS A
FUNCTION OF AC MAGNETIZING CURRENT
FOR BUTTED
SPECIMENS AT
2000 MC.
VARIATIONS IN POWER LEVEL - DB.
15.6
15.4
15.2
15.0
14.8
14.6
14.4
14.2
14.0
13.8
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
A.C. MAGNETIZING CURRENT - AMPS.
1/16" SAMPLE
M.R.L.

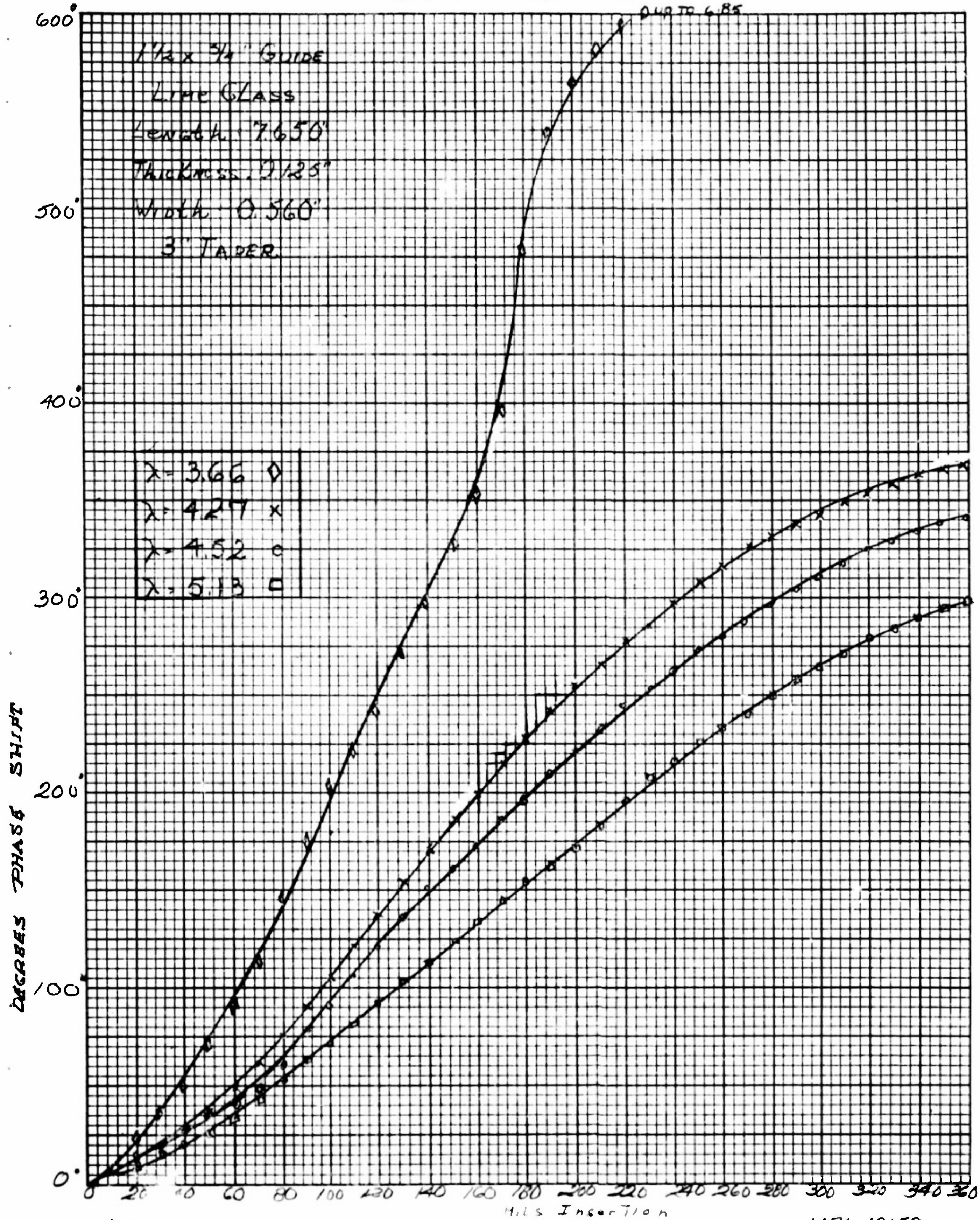


4-53

M.P.I. - 13152

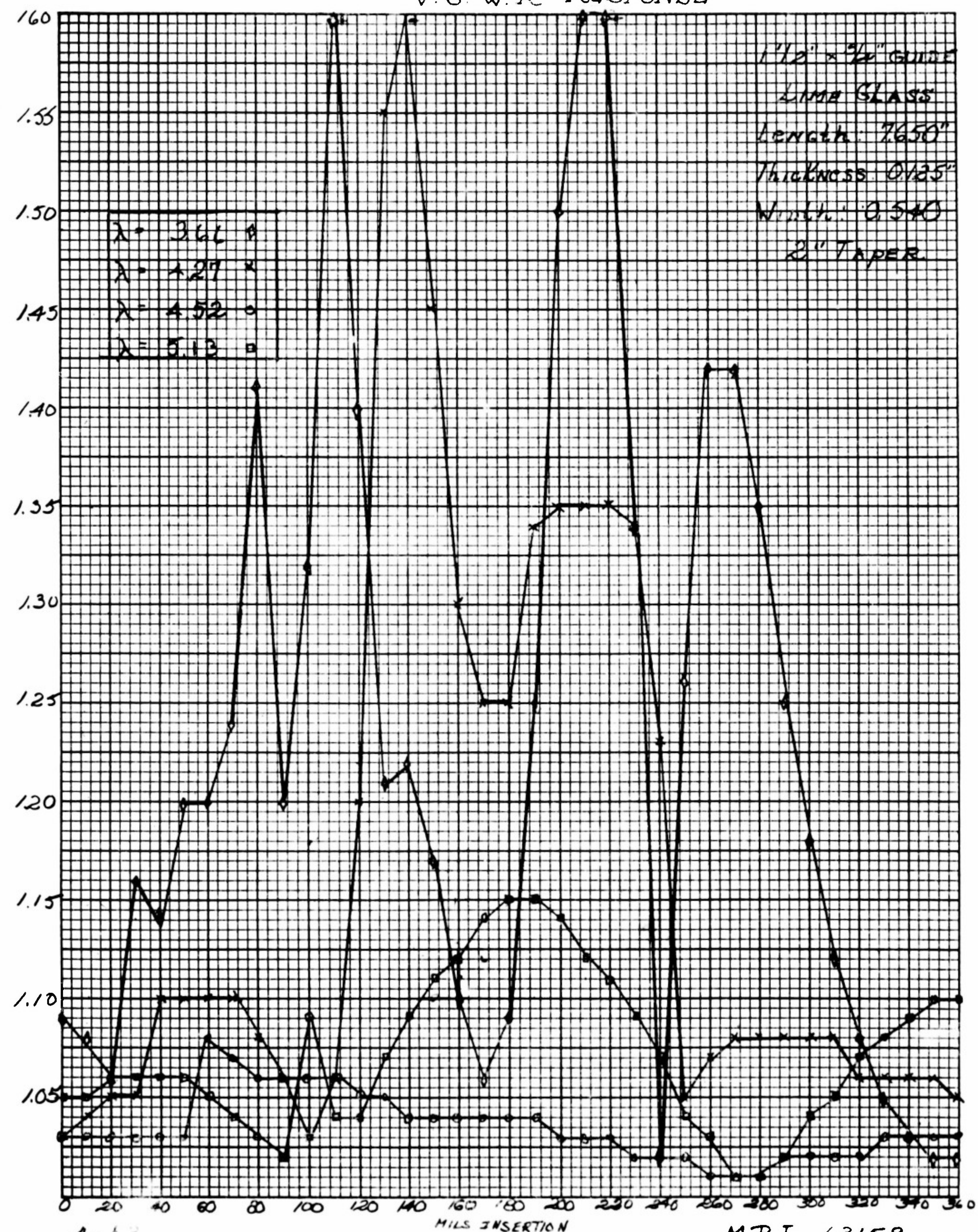

DESIGN OF PHASE SHIFT STANDARD
PHASE RESPONSE
1 1/2" x 3/4" GUIDE
LIME GLASS
Length .7650"
Thickness 0.125"
Width 0.540"
2" TAPER
λ = 3.66 cm.
λ = 4.27 cm
λ = 4.52 cm.
λ = 5.13 cm
DEGREES PHASE SHIFT
640
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
MILS INSERTION
MRI 13157
4-5

DESIGN OF PHASE-SHIFT STANDARD
PHASE RESPONSE



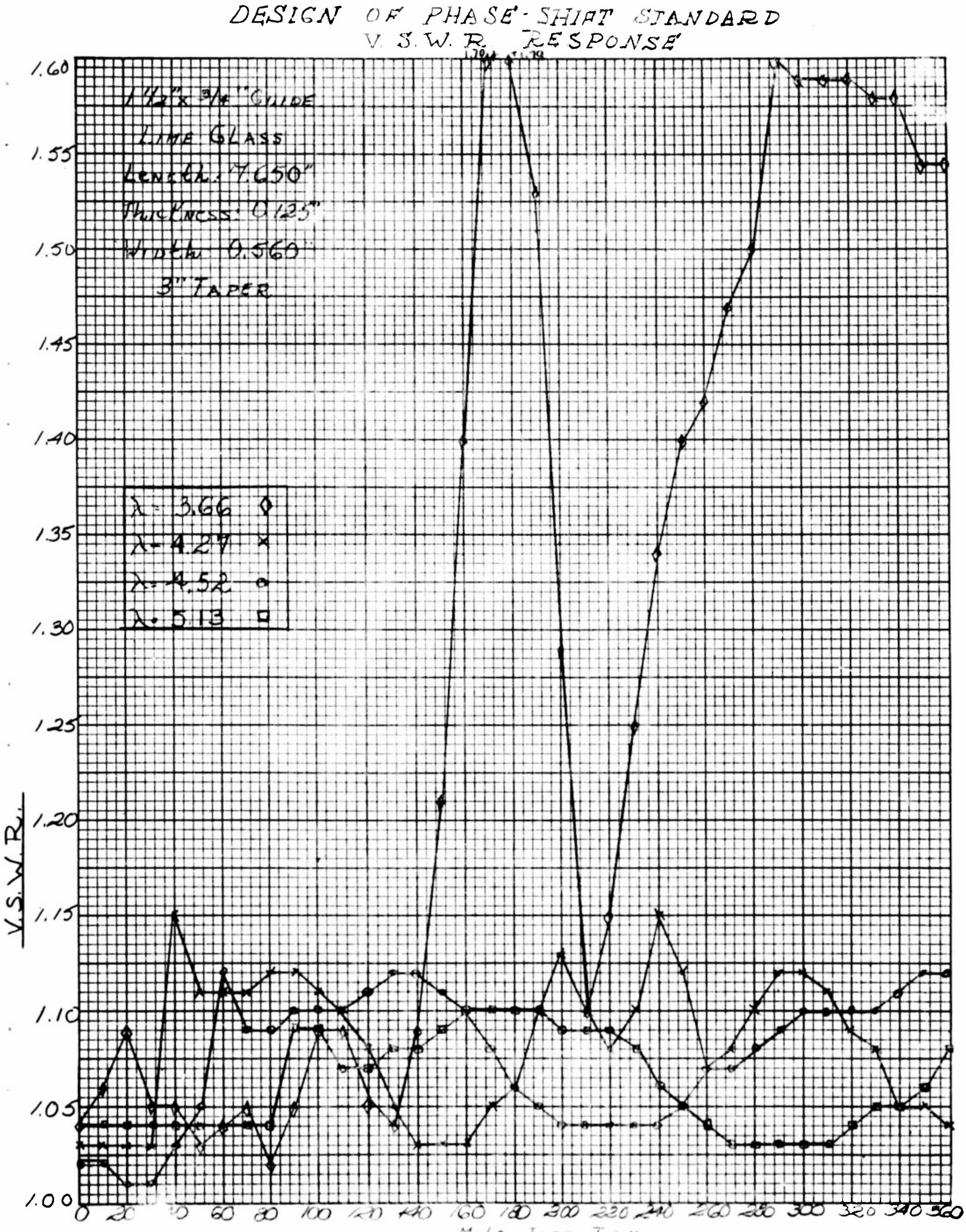
MRI 13159

DESIGN OF PHASE-SHIFT STANDARD
V.S.W.R. RESPONSE



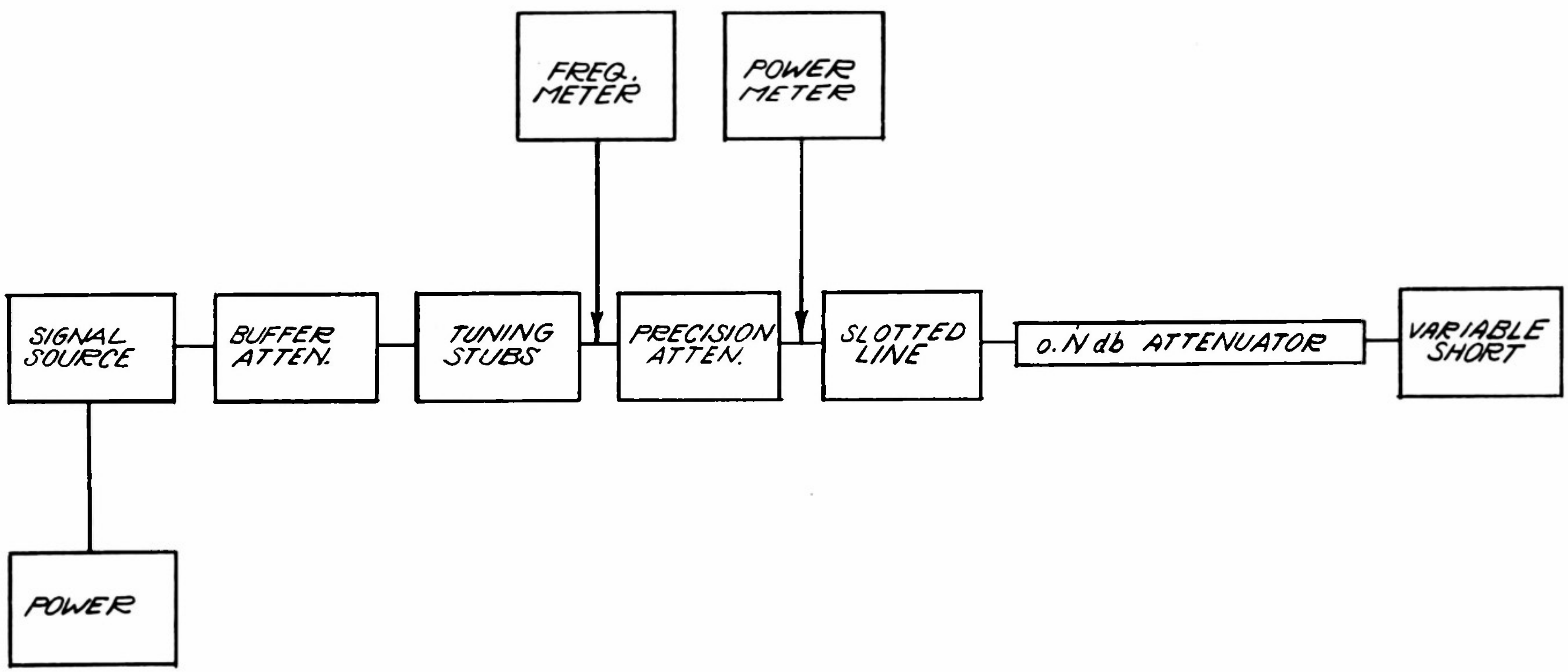
4-

MRI 13158


DESIGN OF PHASE-SHIFT STANDARD
V. S. W. R. RESPONSE
1 1/2" x 3/4" GUIDE
LIME GLASS
Length: 7.650"
Thickness: 0.125"
Width: 0.560
3" TAPER
λ = 3.66 ◇
λ = 4.27 ×
λ = 4.52 ○
λ = 5.13 □
V.S.W.R.
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Mils Insertion

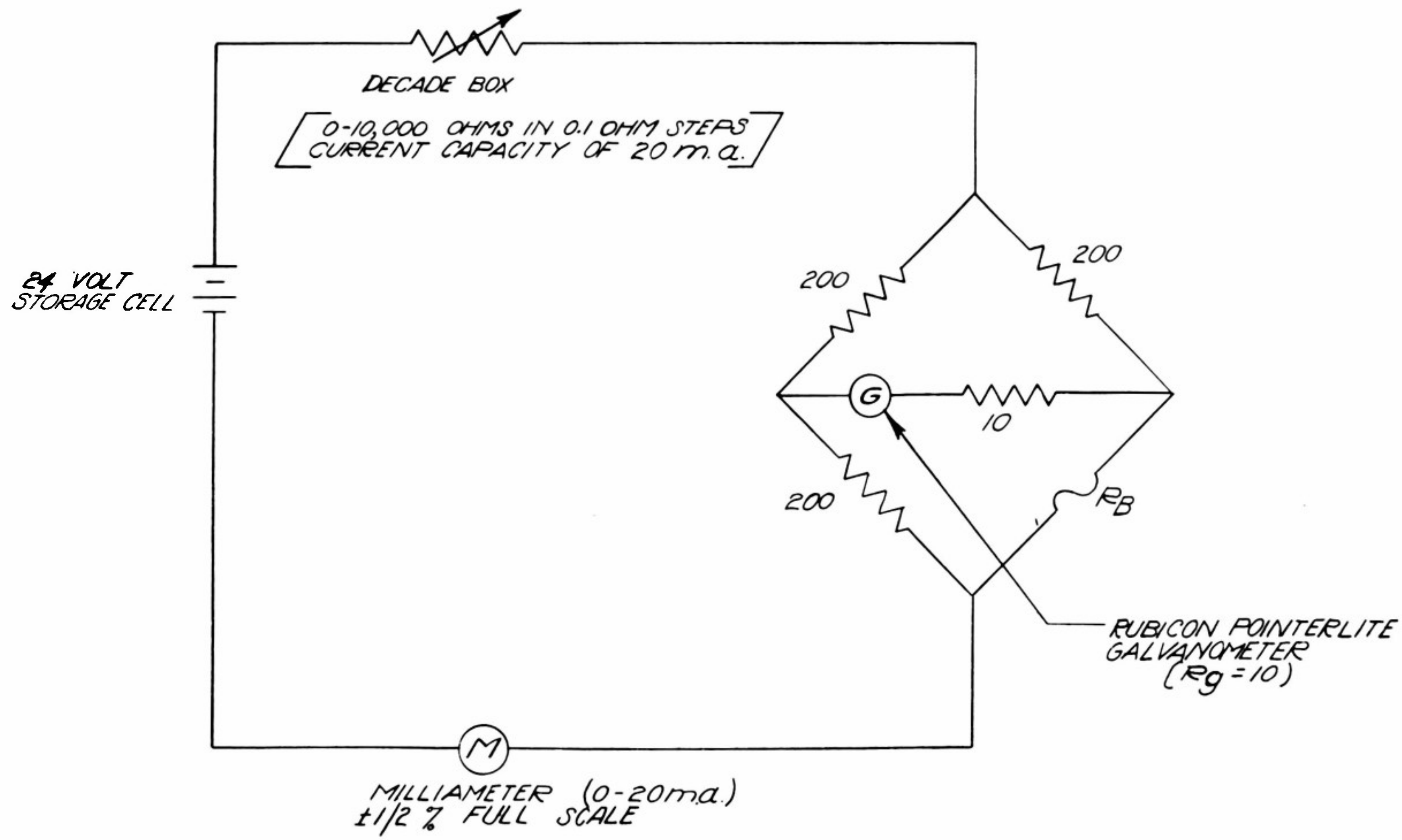
MRI 13160

EQUIPMENT SETUP FOR PRECISION CALIBRATION OF LOW LOSS ATTENUATORS



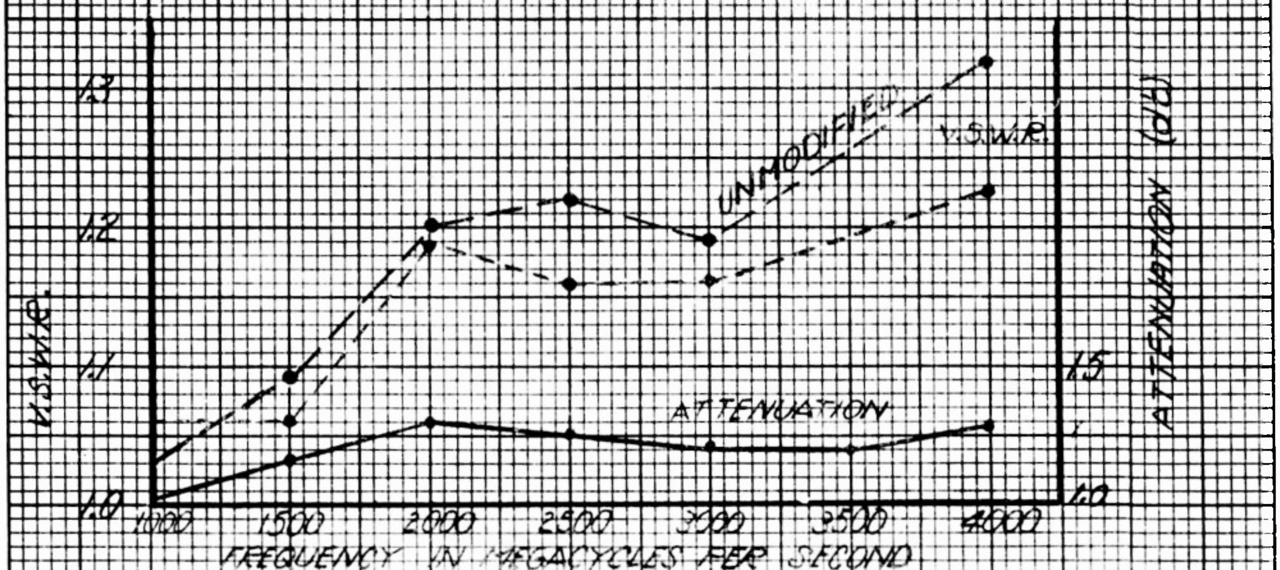
M.R.I. -12410

MICROWAVE POWER BRIDGE WITH CALIBRATED DECADE BOX

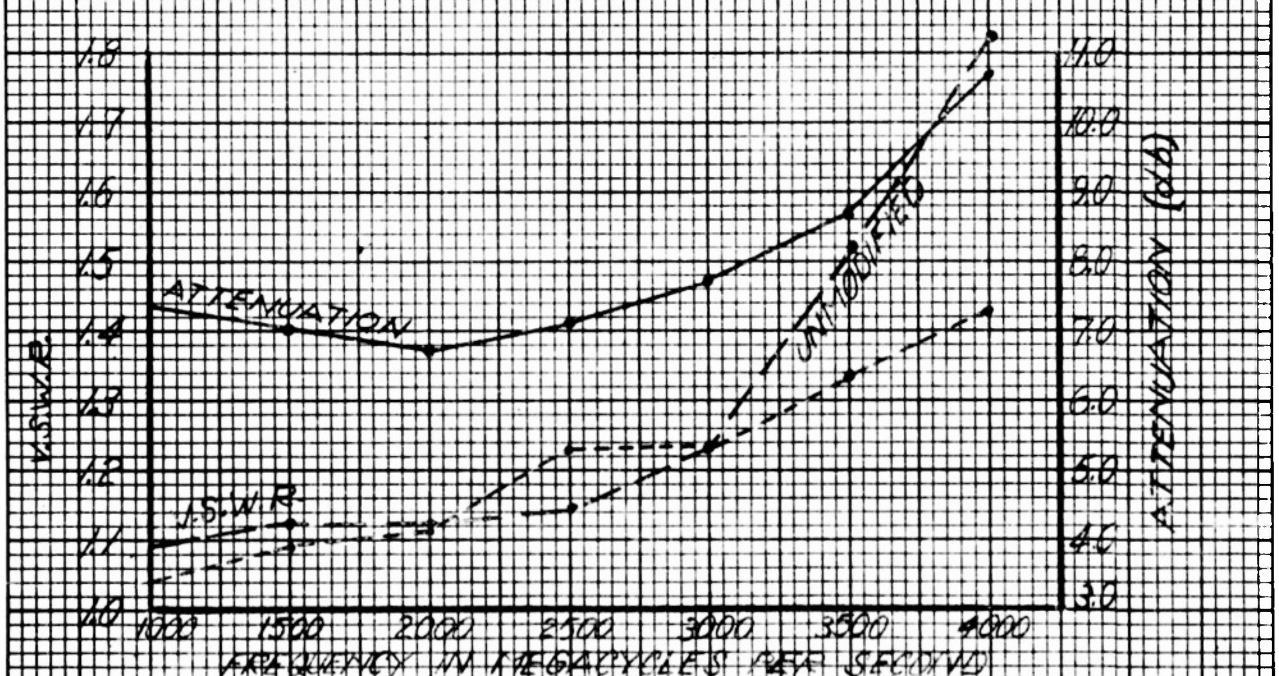


M.R.I.-12642

V.S.W.R. & ATTENUATION CHARACTERISTICS
1000 - 4000 mc/sec
0.8 db NOMINAL **MODIFIED** CHIMNEY TYPE
ATTENUATOR

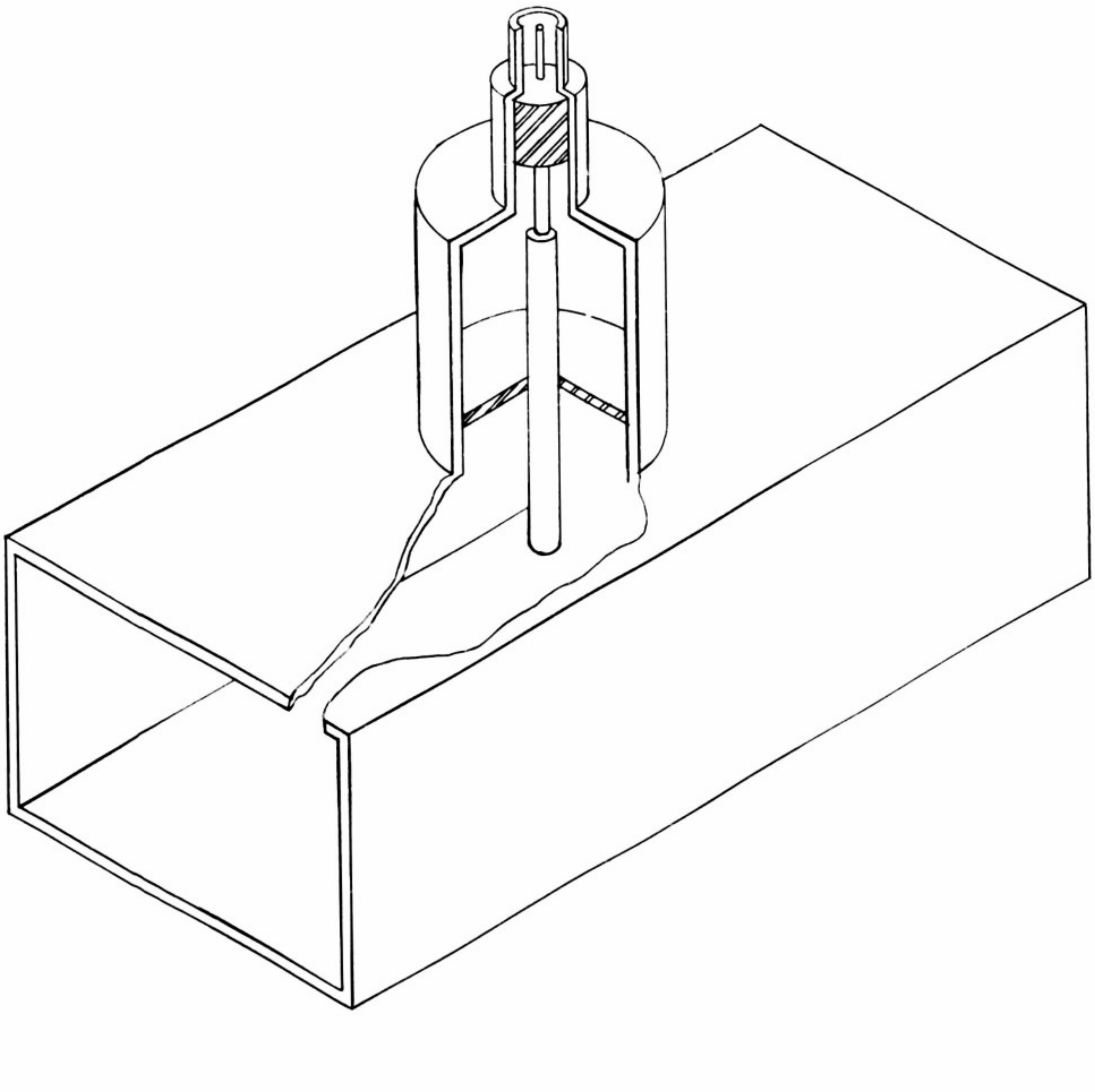


V.S.W.R. & ATTENUATION CHARACTERISTICS 1000-4000 mc/sec.
8.0 db NOMINAL **MODIFIED** CHIMNEY-TYPE ATTENUATOR



M.R.I.-13154

L-BAND PROBE ATTENUATOR



4-53

M.R.I. - 13155

AD 32561

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